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THE PULPING PROCESSES OF TODAY AND THEIR MAIN CHARACTERISTICS

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The pulping processes of today and their main characteristics.

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The population of the world is constantly increasing, and the same thing is true of the paper consumption per head. The vigorous expansion which characterizes the pulp industry of today must be viewed against the background of these facts. In fact, this expansion mainly appears in constantly rising production figures. Alongside this rise in production, however, there is in progress a technical development which partly results in the perfection of processes already in existence, and is partly concerned with long-term changes of a radical nature.

The predominant raw material for the manufacture of paper, board, rayon, and cellulose ethers and esters is the cellulose fibre of hardwoods and softwoods. Further to this, agricultural fibres and other grasses are of importance as raw material for papermaking in countries where suitable types of wood, do not grow. For instance, bamboo is a leading raw material for papermaking in India and other east Asian countries. Straw, bagasse, esparto and reed have also proved themselves acceptable as raw materials for papermaking. Today, about 98 per cent of all the pulp manufactured in the world is made of wood.

Before fibres can be manufactured into paper and the other products mentioned above, they have to be removed from the substances with which they are connected in the plant. This is achieved by means of different pulping processes. Pulping is effected by various combinations of energy in the form of heat, chemicals, pressure and mechanical abrasion. The nature of the resultant fibrous products depends on the type and degree of the treatment utilized.

When wood is used as raw material, there are traditionally two main types of pulp, viz. chemical woodpulp with a yield of about 35 per cent, and mechanical woodpulp with a high yield of about 100 per cent, both on a wood basis. In this respect, the present-day picture is changing radically. It is in fact possible to make types of pulp in any yield desired between 50 and 100 per cent by the modification of already established processes, and by the introduction of new ones. By doing this pulps with quite different properties, and suitable for various purposes, are obtained.

To provide a survey of the situation, the most important old and new processes on a wood basis which are in use today can be arranged in the pattern indicated in Annex I.

In this scheme, the pulps have been classified according to the yield, but it must

be emphasized that there exists no generally accepted basis of division or any accepted nomenclature. A classification which is more correct theoretically might perhaps be made on the basis of the mechanical work needed in order to defibrate the wood after it has been to some extent prepared by chemical treatment. As regards chemical pulps this work amounts to practically zero, whereas the corresponding value for mechanical wood pulp is about 1000 kWh/ton of pulp.

Agricultural fibres may also be treated with some of the pulping processes mentioned, but frequently special processes are employed suited for each kind of fibre used.

After this general introduction, a brief discussion follows of the particular processes.

1. Sulphite Process

The conventional sulphite pulping process is principally based upon the making of chips from logs of wood by means of a chipper, and then pulping the chips in a water solution of acid calcium bisulphite containing an excess of SO_2. Although in its traditional form this process continues to dominate the manufacture of sulphite pulp, the use of bases other than calcium, for example ones which are soluble has recently shown a constant increase in some pulp producing countries. This is especially true with respect to magnesium, sodium and ammonium.

Right up to the second world war, the world production of sulphite pulp was greater than that of sulphate pulp; but now the roles have changed. During the last fifteen years, only very few new sulphite mills have been built, by virtue of the wood species problem, and the enhanced versatility of kraft and semichemical pulp. The most evident advantage of the sulphite pulping processes is that bright and easily bleached pulps are obtained from them. This was especially important when bleaching technique had still not attained a sufficiently high level. However, it is possible today to bleach a sulphate pulp to the same brightness as a sulphite pulp without loosing pulp strength. This satisfactory result has been achieved by the use of chlorine dioxide as bleaching agent. This chlorine dioxide bleaching technique is currently making rapid progress throughout the world. The main raw material for this process is spruce, but hardwoods are also quite commonly used. Nevertheless, this process is not especially well suited for making pulp from one-year plants, but it has in isolated cases been utilized for the manufacture of pulp from bamboo and reeds. The major disadvantage of the conventional sulphite process is the difficulty experienced in pulping some common wood species. Species which are high in resins and certain extractives cannot readily be pulped, and furthermore the logs have to be sound. Pine is one of the species which are impossible to pulp by the conventional sulphite process.

The main chemicals used for the production of pulp by the sulphite process are sulphur and limestone. The consumption of these chemicals is as follows: sulphur about 75 to 100 kg a/ton a. d. pulp and limestone 13 to 18 per cent of a. d. pulp. The consumption varies, dependent upon the pulp quality, the composition of the cooking liquor and the recovery of SO_2. During the whole process of manufacture large quantities of water must be available and this water must be sufficiently clean for the purpose.

However, at the present time the sulphite process is undergoing vigorous development. One of the most obvious improvements is the introduction of evaporation and combustion of the waste liquor. This brings about an improvement in the heat economy of the process, and at the same time the water pollution prob-

lem diminishes. The most thorough-going modification is the introduction of cations other than calcium into the cooking liquor. Magnesium, sodium and ammonium all give easily soluble compounds, a fact which helps the pulping process in many different ways. The penetration of the chips becomes faster, the yield higher, and the properties of the produced pulp are improved. Furthermore, this conduces to the possibility of using pine wood and also barkdamaged logs as a raw material for sulphite pulping.

Magnesium and sodium can both be recovered on the evaporation of the waste liquour and brought back into the process. The conditions are especially favourable as regards magnesium. On the other hand the recovery of the sodium base is more complicated but present day technique has solved this problem also.

The soluble bases also make it possible to carry out "multistage cooks". With sodium as base it is quite possible to start cooking under less acid conditions than in the case of calcium. After the penetration stage, sulphur dioxide may be introduced into the cooking liquor in order to promote the dissolving of substances which must be removed from the wood. Finally, it is possible in particular cases also to give the pulp a purely alkaline treatment. This is of particular benefit when dissolving pulp is being made. In fact, there is every possibility of modifying from a pure sulphur dioxide cook to pulping with caustic soda alone.

Today, sulphite pulp has in many cases had to yield to sulphate pulp; this is particularly so when the pulp is used for the production of extrastrong papers. It must be strongly stressed that the strength of pulp is by no means the essential factor in every connection. In many instances, the strength plays a subsidiary role, while properties such as printability, absorption and so on come to the fore.

The main advantage of the sulphite process is its extreme flexibility. It is possible to produce pulps with properties which are well suited for the most divergent purposes by varying the pulping conditions.

Pulps made by the acid bisulphite process may with advantage be used for making greaseproof and glassine, different kinds of printing papers and tissue papers. It is a part of the furnish for making newsprint. Well purified bleached high α-pulps made by this process are used for the manufacture of rayon and different kinds of cellulose esters and ethers. Bleached sulphite pulps made of bamboo are used for making writing and printing papers, and bristol board, for dissolving purposes and so on.

2. The Mg and Na bisulphite processes

The acid nature of conventional sulphite cooking liquor explains why the fibres are to some extent attacked during the cooking process. In order to avoid this, pulping methods have been developed which are based upon the use of the same chemicals, but with no excess of sulphur dioxide in the cooking liquor. The magnefite process utilizes acid magnesium bisulphite ($Mg(HSO_3)_2$) as chemical, whereas the Arbiso process uses acid sodium bisulphite ($NaHSO_3$). In both cases, the cooking is carried out with no excess of sulphur dioxide.

These processes allow of the use of a variety of wood species, which can if desired also be mixed. They are particularly appropriate for hardwoods. Wood species not previously found suitable for acid sulphite pulping can also be used.

The chemical consumption depends upon a number of different factors such as

the wood species, the type of base, the yield, the cooking temperature and so on. It is doubtful whether any reliable figures can be given with respect to the consumption of chemicals, because of the short time these processes have been in use, but it can be said that chemical recovery is possible, and that this recovery is carried out in a particularly simple and effective way and is already established for magnefite. Both of these processes also use large quantities of good quality water.

In these processes, the cooking may be carried out at a higher temperature, and thus takes a shorter time than in the case of the conventional sulphite cook. The pulp becomes in some respects stronger and the yield higher. These methods are extremely flexible with respect to pulp quality, and appear to be very interesting and promising variants of the sulphite pulping process. Chemical, high-yield and semi-chemical pulps made of chips may be manufactured by these two methods. These pulps are more difficult to bleach than the acid sulphite pulps but easier than the sulphate pulps.

3. Sulphate process

In this process, also termed the "kraft-process", all the known species of wood may be puiped satisfactorily. On a percentage basis, pine is the most used raw material, but an increased use of hardwoods is a typical factor of the development of the present-day sulphate process. This process is also a popular pulping method for making paper pulp out of straw, bagasse, bamboo and reeds. However, esparto is mainly pulped by means of sodium hydroxide alone i. e. the soda process. The sulphate process has always been characterised by effective heat economy and chemical recovery. The evaporation of the waste liquor also consitutes an integral part of this process. The active chemicals are sodium-hydroxide (NaOH) and sodium sulphite (Na_2S). The loss of chemicals during pulping is compensated by the addition of sodium sulphate (Na_2SO_4) to the system. The consumption of chemicals i. e. alkalies calculated as sodium oxide (Na_2O) is about 300 kg/ton of a. d. pulp, or in other words 12 ... 14. 5 kg Na_2O/100 kg wood. A part of the chemicals consumed is recovered and only the rest, i. e. the loss has to be compensated by the addition of sodium sulphate.

The development of the current sulphate process is above all indicated by the expansions of the mills into very large units. That is explained by the method becoming more economic with increase in size of the units. The most noteworthy technical development during the past ten years has been the continuous cooking method already established in many mills.

The paper strengths attained are highest of all chemical pulps. The unbleached pulp is very dark, but it can be bleached to high brightness and strength with the aid of chlorine dioxide. Since chlorine dioxide has joined the family of bleaching agents and has been taken into use, the bleaching of sulphate pulp has become increasingly common, and a relatively large percentage of currently produced sulphate pulps are bleached. Nevertheless, the bleaching requires more stages and chemicals than do sulphite pulps. One advantage of this process is that tall oil and terpentine are produced as byproducts.

In the main, the wood pulp produced by this process is used for making kraft paper and kraftliner. Bleached kraft pulp made of wood has also been used for making food board and different kinds of printing papers. Bleached kraftpulp made of straw, bagasse and bamboo is used for the production of writing and printing papers. Acid prehydrolysis of wood chips prior to normal kraft pulping and bleaching results in a pulp which makes a excellent raw material for dissolving purposes.

4. The semichemical process

Fundamentally, the semichemical process consists of a moderate chemical cook

followed by mechanical fiberizing which completes the reduction of the chips to fibres. All of the chemical pulping processes known at present may be adjusted into the semichemical high yield range by reducing the amounts of chemicals applied, the pulping time and the pulping temperature. The most generally employed semichemical process is the Neutral Sulphite Semi-Chemical process, known in the world market as the NSSC-process.

Hardwoods are the main raw materials for the NSSC-process. Indeed, this process has been developed with a view to finding a use for hardwoods. Usually the cooking liquor is a mixture of sodium sulphite and sodium carbonate, bicarbonate, the sodium sulphite being the major component which serves to delignify the wood. The sodium carbonate neutralizes excess acidity, and thus prevents acid hydrolysis of the pulp. The amount of sodium sulphite required for pulping to a yield of about 75 per cent is normally within the range of 7 to 15 per cent on the basis of the dry wood content. The carbonate generally amounts to about 1/5 to 1/2 of the quality of sulphite.

After having been softened by the chemicals, the chips are transferred to refiners of which the disc type is the most common. During this operation, which is the heart of the process, the chips are reduced to fibres. The consumption of energy for the refining is usually within the range of 300 to 600 kWh/ton pulp.

Semichemical pulp made from wood has many characteristics which make it well suited for use in a wide range of papers and boards. The pulps produced are light in colour, but an increased alkalinity during cooking tends to give a darker pulp. Neutral sulphite semi-chemical pulps are characterized by ease of hydration, low opacity and great strength. NSSC-pulp is especially well suited for the manufacture of corrugating and liner board where an excellent degree of stiffness is an essential requirement. NSSC-pulp may be bleached by the utilisation of large amounts of chlorine and chlorine compounds, yielding a white pulp well adapted for glassine manufacture.

Semichemical pulps have also been produced with straw and bagasse as raw materials. Straw is treated by the monosulphite-method, whereas bagasse is pulped by the NSSC-process. These pulps are mainly used for the production of corrugating board.

The NSSC-process becomes more capable of competing with other methods if the mills are built sufficiently large to make cooking chemical recovery practicable, but smaller plants also can be run on an economic basis. Dried NSSC-pulp is very hard to reslush, and for this reason the NSSC-mill has preferably to be built and to work in conjunction with a board or paper mill using this pulp as raw material. However,it is possible that manufacturing methods devised in the future will eliminate these difficulties.

The distinction between semichemical and chemi-mechanical pulping is that comparatively little dissolving of wood components occurs during chemi-mechanical pulping. All the existing chemi-mechanical processes have their advantages and disadvantages, and at the present time these processes can be classified into two main groups.

1. Processes where pulps are produced from logs
2. Processes where pulps are produced from chips

A discussion of some of the processes falling within these groups follows:

5. Chemigroundwood process

The chemigroundwood process is the main process in the first mentioned category of chemi-mechanical methods, but A. L. B. Semicell may also be considered as belonging to this group.

The chemigroundwood method, developed in the U. S. A., represents an interesting attempt to apply the conventional groundwood process to hardwoods; it includes mild chemical pretreatment of the wood in log form, followed by mechanical defibering in any conventional wood pulp grinder. The pulp is manufactured more succesfully from hardwoods than from softwoods, as coniferous woods do not respond as favourably to this type of chemical treatment.

The cooking liquor consists of a mixture of sodium-sulphite and sodium bicarbonate. The chemical consumption is about 10 - 12 per cent on the basis of o. d. wood. The chemically treated hardwoods are ground with 50 - 60 per cent of the power required for the manufacture of conventional groundwood pulp made from softwoods.

The main advantage of this process lies in the fact that hardwoods may be utilized for purposes which were earlier unpracticable; furthermore, the power consumption is less than for ordinary groundwood. Also, hardwoods are much denser than softwoods, and this allows of the production of approximately 25 per cent more pulp per unit volume of wood than can be obtained from softwoods such as spruce. Against these advantages, the chemical costs and the costs of building the digester house must be taken into consideration.

The pulp produced is much greater in strength than ordinary spruce groundwood pulp, and may be used as a part of the furnish for making newsprint. This pulp may also be bleached with peroxides or calciumhypochlorite.

6. Cold soda process

The cold soda process is the best known and the most widespread of all processes in the second group of chemi-mechanical pulping methods. However, this category also includes some processes used in making chemigroundwood pulp from chips with the same cooking chemicals as those used in the NSSC-process, for instance in the Stora Brite, Blandin and similar methods.

The cold-soda process (mainly employed in the USA) consist of two stages. First ~~of all~~ the chipped wood is treated with alkali without heat. The chips prepared in this way are defibrated in disc refiners. The chemical consumption, calculated on the basis of O. D. wood is 5 - 15 per cent.

The pulp produced is generally used as a part of the furnish for making newsprint; in addition, it has also been used for making food board and corrugated board. The pulp may be bleached with calcium hypochlorite, peroxide or hydrosulphite, and be converted into printing papers, mainly of the magazine-book type.

The main raw materials are northern hardwoods, but good results have also been obtained with semi-tropical hardwoods and eucalyptus. Agricultural residues and grasses may also be satisfactorily pulped by this process.

In 1961, about 50 per cent of all the mills in the world making cold soda pulp were located in the United States; but only a few mills in the world were making pulp by the other mechano chemical processes.

7. The groundwood process

The classical groundwood process was taken into use as early as in 1844, and its development since then has principally consisted of the building of larger and larger units. Nevertheless, within recent years, an attempt has been made in the United States to develop purely mechanical methods of defibration, generally based upon the use of disc refiners i. e. methods making groundwood pulp out of chips instead of the usual logs. Information contained in publications on the subject indicate that the problem has been already solved. It is thus to be expected that a new kind of technique will soon enter this field of pulp making.

The main advantage of the purely mechanical groundwood process is the almost quantitative yield obtained. The raw material generally consists of softwood, and particularly of spruce. The major part of the pulp produced in the world by this process is used in making newsprint. The pulp may be bleached by peroxides and hydrosulphites and converted into different kinds of printing paper. Groundwood pulp is also used for making different kinds of board.

8. Other processes

There follows below a brief discussion of the pulping methods principally used for making pulp out of agricultural residues and other one-year plants.

8(a). The monosulphite process

This process comprises cooking with a solution consisting of sodium sulphite with the addition of sodium carbonate or sodium hydroxide. Semichemical pulp may also be produced by this method. The method is especially applicable to straw and bagasse. The bleached pulp is suitable for the manufacture of writing and printing paper, and the semichemical pulp for making corrugating board. The chemical consumption is as follows neutral sulphite 36-37 kg/100 kg bleached air dry straw pulp, and 10-11 kg sodium hydroxide.

8(b). The soda-chlorine process

Two methods have been developed for making pulp from one-year plants by the aid of chlorine, i. e., the Vain and the Pomilio-Celdecor processes. The latter process is currently used on an industrial scale.

Pomilio-Celdecor is best known for the production of bleached straw and bagasse pulps; the process comprises four principal stages, viz. alkaline digestion, chlorination, extraction with alkali and hypochlorite bleaching. In the ideal soda-chlorine process, the consumption of caustic soda and chlorine are in the proportion obtainable by the electrolysis process of salt. It is important for this process that power is cheap. The method is most suitable for plant material of the non-woody type, and the principal raw materials are thus straw and bagasse.

Subsequent to the first stage, the pulp can be used for making yellow straw papers, straw board and corrugating board. The bleached pulp is very well adapted for different kinds of printing paper. In 1959, there were 28 plants in the world making pulp by this process. Apart from straw and bagasse, esparto is also pulped by the Pomilio-Celdecor process.

8(c). The cold alkaline method

Straw pulp made by a cold sodium hydroxide method is used for making pulp suitable for the production of greaseproof paper. By this method, straw is treated with sodium hydroxide in large chests for 15 days with no application of heat. However, this method is more or less a curiosity.

8(d). The mechano-chemical process

This process is carried out in a hydropulper with no pressure, but at a temperature of 98-99°C with sodium hydroxide or sodium hydroxide and sodium sulphide. The chemical consumption is 14-16 per cent on the basis of oven-dry bagasse. The process is also commonly used for making pulp out of bagasse.

The principal pulping processes used today on a commercial scale and their main characteristics have been briefly dealt with above. Apart from these processes, however, there are also methods which are generally speaking of academic interest alone. Of these, the following may be mentioned.

8(e). Nitric acid is used in France; it has recently also been used in Germany on a small scale, and has been put forward in the United States and Japan for the cooking of agricultural residues. Organic solvents such as alcohols, dioxane and glycols, have been suggested for the pulping of wood. Other agents which have been proposed for pulp-making from wood include chlorine, sodium hydrosulphite, sodium chlorite, klorohydrins and acetic acid. Hydrotropic pulping, using salts of xylenesulphonic, cymene sulphonic and benzoic acids, is one of the most recent methods proposed for the pulping of wood. The Kebra also deserves mention in this connection; it is an early pulping process utilizing sodium salts.

According to the World Review number of Pulp and Paper 1961, there are 55 nations producing pulp. The total production in 1960 of wood, straw, bagasse, esparto, bamboo and other pulps manufactured by these countries rose to 60, 019, 000 metric tons, amounting to a per capita production of pulp in the world of about 20. 5 kg per year in 1960. The paper consumption per head during the same year was 25. 0 kg. Of this world production of pulp 55 per cent is produced in the United States and Canada, 35 per cent in Europe, 7. 7 per cent in Asia, 1. 3 per cent in Latin America, 0. 8 per cent in Oceania, 0. 2 per cent in Africa. About 98 per cent of the pulp produced is made of wood, and the rest of agricultural residues and other one-year plants.

Conclusion

If a pulp mill has to be built, there are many circumstances which have to be considered, both economic and technical in nature.

Which is the pulp most desired in the particular area concerned? Are there sufficient indigenous raw materials suitable for this purpose? By which process may the desired pulp quality be produced from the raw material found in the area? Is this production economic in comparison with purchased pulp - paper? These are but a selection of the questions which demand an answer

When the location of the mill has to be decided upon, the transport costs for raw material vis-à-vis the transport costs for pulp have to be calculated. Furthermore, every pulp-producing mill must have adequate and substantial quantities of water which are sufficiently clean for the purpose. The demands imposed on the quality of the water are greater for bleached than for unbleached pulp production. This is a very important condition to bear in mind.

In the major pulp producing countries, the production units are very big, and within the units the changes brought about by technical development are slow. When new mills are planned, it is possible to apply to the project the most recent experience gained in the field. In the big pulp-producing units mentioned above, however, a long-term process of renewal is in progress.

But in the world today, there exists a large wood reserve still unexploited, particularly as regards pulp and paper making. I am thinking here of the great areas of tropical forest. Although these tropical stands make boast of a variety of trees, only a very few well known species have been utilized

mostly for mechanical wood processing. The species galore which surround these giants may be utilized for pulp and paper making. One difficulty which presents itself is the heterogeneity of these stands, a mixture of species varying in different districts. For this reason it may be a difficult matter to decide upon the most suitable pulping method for each case.

In some instances, the utilization of this raw material for pulp and papermaking may from a technical point of view be regarded as solved, but the economic problems involved will for some time to come preclude the use of this wood reserve to any major extent.

Annex I

Sulphite process
1)Ca(HSO3)2 + SO2
2) Mg(HSO3) + SO2
3) NaHSO3 + SO2
Bisulphite methods
1) Magnefite Mg(HSO3)2
2) Arbiso NaHSO3
Sulphate process NaOH + Na2S
Neutral Sulphite Semi-Chemical Process Na2SO + Na2CO3 NaHCO3 NaOH
Cold Soda method NaOH
Chemigroundwood method Na2SO3 + NaHCO3
Groundwood
Chemical treatment
Chemical + moderate mechanical treatment
Moderate chemical + mechanical treatment
Mild chemical + mechanical treatment
Mechanical treatment
Chemical pulp Yield 40-55 %
Chemical high yield pulps Yield 56-65 %
Semi-chemical pulps Yield 65-85 %
Chemi-mechanical pulps Yield 85-90 %
Mechanical pulps Yield 90-96 %

538 E - Oct. 1962 - 1,600